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LAMINATED MULTI-LAYERED WOVEN TEXTILE FABRICS FOR USE IN AIR HOLDING VEHICLE RESTRAINT SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to provisional application No. 60/293,613, filed May 25, 2001.

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to automotive protective devices such as inflatable air bags, side air curtains, or the like. More particularly, the invention relates to a laminated multi-layered woven textile fabric having pre-configured air holding cavities for use in side air curtains, a composite film product having adhesive and sealing properties useful in the manufacture thereof, and a method of manufacturing said product.

2. DESCRIPTION OF THE RELATED ART

Currently available safety restraint devices for automotive vehicles include driver and passenger side air bags that are rapidly inflated by a gas – commonly referred to as "air" – which is produced by the ignition of a pyrotechnic material at the moment a collision begins. These devices provide a protective barrier between the vehicle occupants and the vehicle structure. Much of the impact of a collision is absorbed by the air bag, thus preventing or substantially lessening the possibility of serious bodily injury to the vehicle occupants. Air bags are typically stored in a collapsed, folded condition in the steering wheel to protect the driver, and in the dashboard to protect a front seat passenger. The automotive industry has recently introduced side air bags that are stored in the back of

the front seats or in the rear seats to protect the cabin occupants in the event of a collision occurring on either side of the vehicle. More recently still, a further safety feature that has been made available for passenger vehicles, especially light trucks, sport utility vehicles (SUVs) and minivans, is the side-impact protective inflatable side air curtain that is designed to provide a cushioning effect in the event of side collisions or rollover accidents. These side air curtains are stored uninflated along the roof of the vehicle or in one of the main support pillars of the vehicle. In the event of a collision the side air curtain deploys along the interior side walls of the vehicle cabin, protecting the occupants from serious bodily injury from contact with the vehicle structure (support pillars, etc.) and from broken glass. They must also be designed to prevent the passengers from being thrown from the vehicle in rollover conditions, which is one of the principal dangers in an SUV accident.

Each of these various types of air bags has different design and physical property requirements, such as gas (air) holding ability or, alternatively, permeability, air pressure and volume, and puncture resistance. For example, the driver side and front passenger side air bags, which deploy in about 0.06 seconds, require very little or no gas retention ability since they are designed to inflate and then to deflate almost immediately after inflation. Passenger side air bags require a controlled permeability, which enables them to lose air more gradually, but still remain inflated for only a few seconds. Side air curtains, on the other hand, must retain air pressure and volume for relatively longer periods of time than other types of air bags to protect cabin occupants in rollover accidents, which can take up to 10 seconds or more to complete. Additionally, to be commercially acceptable, all vehicle air restraint devices must have superior packageability and anti-blocking properties, which permits them to be packed into a relatively small space, such as within a steering wheel or a vehicle support pillar, and to deploy instantaneously when needed without the

material sticking to itself after being stored for relatively long periods of time, perhaps even years. These and other physical properties are determined in large part by the type of fabric and weave used in the air bag, whether the fabric is knitted, woven or non-woven, and, importantly, the nature of the coatings that are used on the fabric. Coatings of various types are used to seal the fabric of the air bag and make it air holding.

Wherever coated fabrics are used, considerations such as controlling air permeability, air pressure, and volume exist. Adhesion of the coating material to the textile fabric substrate also presents a serious problem that must be addressed. For example, it is generally more difficult to obtain strong adhesion of a coating material to textile fabrics having a smoother surface than it is with fabrics having a rougher surface. Radio frequency (RF) heat sealing techniques cannot be used with some coatings such as silicone rubber (polysiloxane) to form the air bag because this material will not flow at RF heat sealing temperatures. In such cases, air bags are usually made by stitching, a process that will frequently require the addition of an adhesive sealant in the stitched areas to prevent leakage of air. Even with such adhesive sealants, however, some leakage of air occurs at the stitching, which lessens the protective capability of the air bag.

The air holding capability of a side air curtain is critical since it must remain inflated for extended periods of time to protect passengers in automotive accidents involving multiple rollovers. Unlike driver side and passenger side air bags, which are designed to inflate instantaneously and to deflate almost immediately after inflation to avoid injury to the driver and front seat passenger, a side air curtain must be capable of remaining inflated for from about 3 to about 12 seconds, depending upon the size of the air curtain and the size and type of vehicle involved. An average passenger vehicle would require a side air curtain of from about 60 inches to about 120 inches in length measured

along the side of the vehicle. A larger vehicle, such as a minivan, would require an even longer side air curtain. The inflation period of a side air curtain should be sufficient to protect the cabin occupants during at least three rollovers, the maximum usually experienced in such incidents.

Side air curtains are also designed to be configured to different sizes and shapes depending upon the type of vehicle in which they are to be deployed. Thus, the size and shape of the air curtain will vary depending upon the make and type of vehicle. For example, a minivan is likely to require a different configuration of side air curtain than an SUV. The distance and location of the vehicle's support pillars and the height of the vehicle must also be taken into consideration when designing an air curtain. Since side air curtains are relatively large in comparison with driver or passenger side air bags, the gas pressure available for their expansion, which is limited in volume by the amount of pyrotechnic material available, must also be effectively employed. This is accomplished by designing side air curtains that have air holding cavities only where they are needed to protect the passengers. Those areas where no protection is required have no air holding cavities, thus reducing the volume of gas required to inflate the device to the desired pressure. When side air curtains are deployed they may be subjected to extreme pressures within a relatively broad range depending upon their specific location or application. Air bag deployment pressures generally range from about 50 kilopascals (kPa) to about 450 kPa, which corresponds generally to a range of from about 7.4 pounds per square inch (psi) to about 66.2 psi. Accordingly, there is a need for fabric products and methods of construction for air bags that are versatile both in terms of accommodating the demand for varied sizes and shapes, and which will also be relatively light weight and relatively impermeable to fluids under such anticipated pressures.

Typically, an air bag is constructed by joining two or more woven textile fabrics, each of which has been pre-coated with a sealing material to maintain air pressure when the bag is inflated. The pre-coated fabric is configured to the desired shape as, for example, by cutting, and the separate pieces are then sewn or welded together. Frequently, they are both sewn and welded for strength and air holding purposes. Air holding capability in vehicle restraint devices has been accomplished through the application of coatings such as chloroprene and silicone rubber to a textile fabric (e.g., nylon). Menzel, U.S. Patent No. 5,110,666 discloses a woven nylon fabric coated with polyurethane to provide the desired permeability and retention of inflation gas. Improved polyurethane, acrylic, polyamide, and silicone coatings that are coated in layers on the fabrics have recently been developed. It has been found that adhesion and heat sealing characteristics are greatly improved with such layered coatings. Examples of such coated fabrics and methods of coating such fabrics are disclosed in commonly assigned abandoned applications Nos. 09/327,244 and 09/327,245, filed June 7, 1999, and U.S. patent No. 6,239,046, issued May 29, 2001, the disclosures of which are incorporated herein by reference and made a part of this disclosure. Another example of a greatly improved bonding system is a polyurethane epoxy resin and polysiloxane beaded heat seal, which is disclosed in copending commonly assigned application No. 09/452,030, filed November 30, 1999, which is incorporated herein by reference and made a part of this disclosure. Further developments in air bag technology are disclosed in commonly assigned copending applications, No. 09/459,768, filed December 13, 1999, in which the inflatable safety device incorporates connective tethers within the restraint device to provide structural support and stiffening when it is inflated, and No. 09/572,176, filed May 17, 2000, which relates to a sewn fusion seal process for producing air holding vehicle restraint systems

such as those disclosed herein, both of which are incorporated herein by reference and made a part of this disclosure.

Shigeta et al., U.S. Patent No. 5,302,432, discloses a driver side or passenger side air bag, not an air curtain, in which a film of polyolefin resin and a non-woven material is laminated to a woven synthetic fabric, such as nylon. The polyolefin film is laid down on the woven fabric in molten form and, as such, adheres to the fabric. The non-woven material is bonded to the molten resin and forms the outer surface of the device. The purpose of the non-woven material is said to be twofold: to provide for the escape of air after inflation of the bag, and to protect the driver or passenger, as well as the film, from the hot inflation gas. Such a construction would be undesirable in a side air curtain in which air retention at relatively high pressures for relatively long periods of time is required. Further, the woven multi-layered textiles of the present invention have pre-configured air holding cavities, which would be subject to leakage of the molten film through the fabric when coated and cause sticking, which would impede the deployment of the device when needed. Similarly, Kitamura, U.S. Patent No. 5,707,711, discloses an air bag, not an air curtain, constructed from a seamless tubular woven fabric to which a polymer resin such as polyurethane is laminated to prevent permeation of gases through the surface of the bag. The resin may be applied as a liquid coating or as a film, which is laminated to the fabric by heat and pressure. However, this prior art does not disclose a method by which a pre-configured multi-layered air bag structure, having the desired shape for use in a particular make and size vehicle, can be laminated in one pass with a coating in film form, thus providing an efficient, cost effective means of producing such a bag.

Instead of sewing or welding pre-configured pieces of coated textile fabric, it is much more economical in terms of cost of production and ease of shipping to weave the

side air curtains directly on a loom to produce a multi-layered woven product having pre-configured air holding cavities and the size and shape curtain desired in the final product. Pre-configured woven side air curtains require minimal cutting and essentially no joining of separate pieces, and are ready for coating as they come off the loom. Since the multi-layered fabric is woven from uncoated yarn, the curtain must be coated after weaving to impart the desired sealing and adhesive properties to the product. The difficulty inherent in coating a pre-configured multi-layered woven product is that the liquid coating material, e.g. polyurethane, can soak through the outer layers of woven fabric and penetrate the interior of the curtain. When this occurs and the coating hardens with heat and pressure, the sides of the curtain will stick together, preventing or substantially hindering the opening of the air pockets and deployment of the curtain when it is needed. Moreover, in order to make the side air curtain impermeable to air, the coatings require large concentrations of polysiloxane or other rubber-like materials. These produce a very heavy and bulky curtain that is not easily folded and stored when not in use. The present invention provides a laminated pre-configured side air curtain, a multi-layered composite film product that can be used in the lamination process, and a novel lamination process for manufacturing the side air curtain.

SUMMARY OF THE INVENTION

This invention relates to an automotive protective device comprising a multi-layered woven textile fabric having pre-configured air holding cavities and a polymeric film laminated to the outer surfaces thereof to make it air tight to very high pressures for extended periods of time. In the process of making the air curtain of this invention, an adhesive polyether polyurethane or polyester polyurethane prime coat layer is first coated onto a pre-configured, multi-layered, woven textile substrate, and then a polymeric film, such as polyamide, polyolefin or polyurethane is laminated thereto. In one embodiment of the invention, the adhesive prime coat layer is applied to the outer surfaces of the multi-layered textile substrate, which can be woven nylon, polyester, or other synthetic fibers, through rotogravure or direct coating and allowed to dry. A solid polymeric film, such as polyamide, polyolefin or polyurethane film, is applied to the prime-coated textile substrate by means of hot film lamination, through the use of heat and pressure. In an alternative embodiment of the invention, a multi-layered composite film product is disclosed, which can be used as a film laminate without the need for first applying a prime coat adhesive layer to the textile substrate. In this connection, the adhesive prime coat and the polymeric film laminate are applied to the textile substrate in a single step via the film laminate itself. The methods and products of this invention thus permit an automotive protective device such as a side air curtain to be pre-configured or prefabricated to numerous varied designs and shapes prior to coating which will result in economies of operation and reduce the cost of manufacturing these devices.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top plan view of a position of a sheet of the multi-layered woven textile substrate unwound from a supply roll, showing multiple units of pre-configured side air curtains with air holding cavities;

Fig. 2 is a diagramatic view from the left side of the wind, unwind, layering and heat laminating steps performed on the various materials according to one embodiment of the invention;

Fig. 3 is a diagramatic view of a segment of the hot lamination steps of the method of the invention;

Fig. 4 is a cross-sectional view of the multi-layered, pre-configured textile substrate shown in Fig. 1 with film lamination;

Fig. 5 is a cross-sectional view of one embodiment of the composite film laminate of the invention;

Fig. 6 is a schematic plan view of a multi-layered textile substrate with a pre-configured construction showing exemplary tethers and one exemplary dead air zone;

Fig. 7 is a schematic cross-sectional view of a multi-layered textile substrate of a pre-configured construction, with tethers;

Fig. 8 is a schematic cross-sectional view of a tethered air curtain; and

Fig. 9 is a schematic plan view of a multi-layered air curtain, illustrating another embodiment of tether.

DETAILED DESCRIPTION OF THE INVENTION

It has been found that by hot laminating a solid polymeric film of polyamide, polyolefin or polyurethane material to the outer surfaces of a multi-layered woven textile substrate having pre-configured air holding cavities to produce an automotive protective device such as a side air curtain, the pre-configured air cavities will hold air at very high pressures for extended periods of time. The multi-layered textile substrate can be a woven nylon, polyester, or other synthetic fiber, all of which are well known in the art to be useful in the manufacture of air bags and side air curtains. According to the method of the invention, the outer surfaces of the textile substrate are first coated with an adhesive prime coat to seal the fabric and provide a base to which an overlying polymeric film layer can be laminated. The prime coat material is formulated to be suitable for coating the textile fabric without soaking through the textile to the interior of the air holding cavities and causing sticking or blocking which would prevent its opening when it is activated. In another embodiment of the invention, the polymeric film layer comprises part of a composite film structure that also includes an adhesive prime coat layer, which eliminates the need for a separate prime coating step.

The adhesive polyurethane prime coat comprises a solution of an aliphatic or aromatic polyester polyurethane or polyether polyurethane based material that is compounded with such other materials as weight stabilizers, heat stabilizers, flame retardants, colorants and blocked isocyanate. The presence of isocyanate is important in the inventive process because when sufficient heat and pressure is applied to the prime coat composition, the isocyanate becomes adhesively activated. At this point in the process, the polyurethane becomes reacts with and adhesively binds the overlying polymeric film layer. The result is a thermoset film-primecoat composite which adheres to the textile fabric,

seals it and makes it air tight and able to withstand high pressures for the relatively long periods of time required of an air curtain.

The polyurethane prime coat is formulated to have a solids content of from about 25% to about 45%, with about 35% solids being preferred, and a tensile strength when in film form of from about 150 psi to about 250 psi. The tensile strength of the polyurethane prime coat when in film form is an indication that the prime coat formulation is suitable for coating a woven textile fabric for use in the invention.The coating weight of the polyurethane prime coat on the textile fabric can be from about 0.25 ounces per square yard (osy) to about 2.5 osy, with about 1.0 to about 1.2 osy being preferred. In one embodiment of the invention, a multi-layered, woven textile substrate is first coated on both outer sides with a prime coat layer of polyurethane. The liquid prime coat material is laid down substantially evenly over the pre-configured woven textile substrate, e.g. by a knife over roll process (not shown in the drawings) in a coating line at a temperature elevated sufficiently to evaporate the solvent in the formulation without activating the isocyanate. A suitable temperature would be from about 250° F. to about 300° F. to as high as 325° F. It is important that the isocyanate not be activated at this stage in the process because otherwise the prime coat will be prematurely cured and the polymeric film laminate, which is applied at a later stage of the process, will not adhere to the surface of the woven textile fabric.

In the film lamination step in the process of the invention, a solid polyamide, polyolefin, polyester or polyurethane film is laminated to both outer surfaces of the prime-coated, pre-configured, multi-layered woven textile substrate to produce a film-textile-film laminate. The polymeric film laminate of the invention has a thickness of from about 0.2 mils to about 5.0 mils, and preferably from about 0.5 mils to about 1.0 mils.

In one embodiment of the invention, as shown in Fig. 1, a roll of woven multi-layered textile substrate 10, having a multiplicity of pre-configured side air curtains C, is unwound, prime-coated on both top and bottom outer surfaces, dried, without activating the isocyanate, and rewound for later film lamination, which takes place in a separate second operation. In the method of the invention, as shown in Fig. 2, a roll of pre-prime-coated, multi-layered woven textile fabric 10 is unwound from roll 10a and pulled in direction D_1. Simultaneously, rolls of polyamide, polyolefin, polyester or polyurethane film 11 and 12 are unwound from rolls 11a and 12a, respectively, and pulled in directions D_2 and D_3, respectively, so that they contact the textile fabric 10 on sides B and A, respectively. The film-textile-film composite is then drawn, under pressure, over hot roll 13 where Side A is film laminated first, and thereafter over hot roll 14 where Side B is film laminated. The film-textile-film laminate is then rewound at roll 15 for shipment and further processing into an automotive protective device, such as a side air curtain.

During the lamination process polymeric film laminates 11 and 12 are laminated separately and sequentially to opposite outer sides of the precoated woven textile fabric 10. As shown in Fig. 2, film 12 is laminated under heat and pressure to side A of the textile fabric 10 by contact with hot roll 13, while film 11, which is in contact with the opposite side of the textile fabric, away from hot roll 13, is not laminated at this point in the operation. When the film-textile-film composite is pressed against hot roll 14, film 11 is pressed against heated roll 14 and becomes laminated to side B of the textile fabric at that time and place. Film lamination takes place at hot roll temperatures of from about 275° F. to about 450° F., preferably at about 400° F., and at pressures of from about 200 pounds per square inch (psi) to about 1000 psi, with from about 500 psi to about 600 psi being preferred. The film laminate has a thickness of from about 0.2 mils to about 5.0 mils, with

from about 0.5 mils to about 1.0 mils being preferred. It is to be understood that the sequence of film laminating steps described above is exemplary only, and variations thereof can be made to accommodate various manufacturing requirements.

Details of the hot lamination step of the method of the invention at hot roll 13 is shown in Fig. 3, where lamination of film layer 12 to side A of the textile fabric takes place. In addition to hot roll 13, the associated structure includes feed rolls 17 and 17a, high pressure roll 18, and blanket 19. Pressure is applied after the initial wrap takes place to heat-activate the prime coat, which is coated on the woven textile fabric. To prevent air bubbles from forming between the layers of film laminate 11 and side B of the textile substrate 10, endless blanket 19 extends partially around hot roll 13 to keep film layer 11 in position against side B while film 12 is being laminated. Film 11, which is separated from hot roll 13 by the woven textile at this point in the operation, is not laminated. Lamination of film 11 to side B of the textile substrate takes place at hot roll 14, shown in Fig. 2, in which there is no need for a blanket to hold the film layer as shown in Fig. 3. The multi-layered textile fabric, laminated on both sides A and B, is then wound on roll 15, shown in Fig. 2. A cross-section of the laminated multi-layered woven textile fabric taken across line 4-4 of Fig. 1 is shown in Fig. 4, wherein polymeric film coatings 11 and 12 are shown laminated on sides B and A, respectively, of textile fabric 10. The polyurethane prime coat layer 9 is shown between the film layer and the textile fabric. Suitable tethers 34 are provided to limit expansion of the fabric layers when the protective device is explosively deployed, and to maintain the desired expanded shape of the air curtain. Integrally woven connectors 44 and 45 between the multi-layered portions of the device are shown in Fig. 4.

In an alternative method of the invention, a multi-layered woven textile fabric is

laminated by film transfer with a composite film structure that comprises both the polymeric film layer and the adhesive prime coat layer. In this embodiment, the composite film is applied to a pre-configured, multi-layered woven textile fabric in one step rather than two, thus eliminating the need for a separate prime-coating step. As shown in Fig. 5, the composite transfer film 20 is formed by casting a solution of polyester, polyamide or aromatic or aliphatic polyether polyurethane or polyester polyurethane material onto release paper 21. The carrier film layer 22 has a thickness of from about 0.2 mils to about 5.0 mils, with from about 0.5 mils to about 1.0 mils being preferred. Typical solvents for the carrier film are toluene, xylene, and dimethyl formamide (DMF). A prime coat layer 23 of polyester polyurethane or polyether polyurethane polymeric material is coated onto carrier film layer 22. The prime coat layer has a thickness of from about 0.5 mils to about 5.0 mils, with from about 1.0 mils to about 1.5 mils being preferred. When the coating process has been completed and the film composite dried, the release paper is stripped away and the composite transfer film wound on a roll. It is then ready for the lamination step, at which time it is laminated to the multi-layered woven textile substrate in the manner shown in Figs. 2 and 3. In this embodiment of the invention, there is no need to pre-primecoat the woven multi-layered textile substrate.

Once the multi-layered woven textile substrate is film-laminated on both outer surfaces, the air holding cavities of the device, when inflated, will be substantially air tight. When deployed, these protective air bags will hold air during a rollover accident for the entire rollover period. When laminated in accordance with this invention, air curtains having an initial inflation pressure of about 70-75 kiloPascals (kPa), will hold to a minimum of about 60 kPa for about 10 to 12 seconds after inflation. Specific air cavity designs will alter the volume of air and the amount of pressure required. These multi-

layered textile substrates are designed to have different air cavity configurations and different internal tether designs as shown in Figs. 6-9. In Fig. 6 there is shown a top plan view from the side of a multi-layered woven textile substrate with a pre-configured construction 30 of the invention, including a dead air zone 31 (not inflatable) and internal tethers 32, 33 and 34, which maintain the air curtain's configuration and keep it from pulling apart during inflation. Fig. 7 is a cross-sectional view of a multi-layered textile substrate 40 with internal air channels 41, 42 and 43, and integrally woven connectors 44 and 45. Tethers 34 are provided to control expansion and maintain the desired shape of the air curtain.

Fig. 8 is a cross-sectional view of a tethered side air curtain 50, showing internal tethers 51, 52 and 53 which limit the expansion of the side air curtain and maintain the shape when in the expanded state.

Fig. 9 is a top plan view of a multi-layered tethered side curtain 60, having a multiplicity of tethers, such as that shown at 61. It is generally considered difficult to coat a multi-layered fabric similar to that shown in Fig. 8 with applied coating techniques or rotogravure direct coating without resulting in penetration through the textile material to the tethers. Unwanted gluing together of the tethers must be avoided because they are intended to open and expand when the bag is inflated. The air bag panels typically consist of nylon yarns of different deniers (D), such as finer deniers on the order of 235 D to 350 D or 420 D. However coarser deniers, such as 630 D and 840 D are used in those places where the tethers are attached to provide additional strength to keep the bag open while inflated and to avoid having a bag burst. Heavier denier yarns are coarser than finer deniers and the polyurethane prime coat could more easily penetrate those areas than where the finer denier yarns are used. Thus, the process in which a multi-layered

composite film laminate is used permits the use of higher denier yarns, including up to 840 D, since the prime coat is overlaid on the multi-layered woven textile substrate while in the solid state. This reduces the possibility of penetration into the interior of the textile fabric and enables the bag to inflate evenly, as designed, to a specific volume and configuration.

The process described also permits the use of coarser deniers which enables the configured internal parts of the bag design to be expandable. In some cases this will produce a much better bag design that will prevent the occupants of the vehicle from impact against a pole, pavement, or window of the vehicle. These types of air curtains and air bags will have a much better resistance to occupant impact because of their pillow-like effect in performance. Further, the process enables the air bag designer to configure and locate tether designs anywhere in the desired configuration of the bag design.